March 31, 1958

Dr. Lyman Spitzer
Princeton Observatory
Princeton, N.J.

Dear Dr. Spitzer:

In connection with the theoretical problems of the definition and evolution of "living systems" my reading has brought to my attention the fascinating problems of the composition and evolution of interstellar matter. I was especially struck by the analogy between the growth of the interstellar grain and that of a hypothetical proto-organism. Let me say at the outset that my information on the subject is limited almost entirely to what I could get out of Dufay's book in its recent English translation.

From Dufay, and from your paper with Bates (Ap. J. 113, 441, 1951) I gather that the earliest steps in the theory of grain formation are the most troublesome, especially the very low rate of the initial diatomic reactions, C + H -> CH etc. I note that Hoyle tries to solve this problem by supposing that the corpuscular emission from some stars occurs at a sufficient density of C atoms to allow of the condensation of soot (viz C-C-C-) which would survive as nuclei. Howbeit, there is one thought on this problem which comes almost automatically to a geneticist, and which I have not seen mentioned in my own very cursory reading. Dufay cites two types of reaction following the collision of grains: fusion and vaporisation, but these are not especially helpful. However, should there not be a third effect, from collisions of intermediate energy, namely the fracture of grains? This could provide a growth mechanism whereby even a very limited initial number of nuclei could increase to meet the theoretical requirements. It would be analogous to the autocatalytic increase of the first organisms. Has there been any effort to work out a dynamic theory which would include the postulated <u>fission</u> of grains?

The most obvious obstacle might be the low rate of collision of small grains. This leads to the question whether there might be other fission processes besides fractures and spallation by collisions of grains with grains and with smaller particles. If the grains include molecules other than hydrides, C-N, C-O and C-C bonds might be broken by photodissociation, particularly of those bonds which have a high specific absorption in the ultraviolet and therefore lead to high equilibrium temperatures. The fragments might still be able to serve as nuclei. For example, if R is the 'rest of a grain' we might have by successive accretions something like this:

$$R- \xrightarrow{C} R-C- \xrightarrow{H} R-CH \xrightarrow{H} R-CH_2 \xrightarrow{C} R-CH=CH \longrightarrow R-CH + CH.$$

The CH is then available as a nucleus, in addition to the R-CH. Of course, the scission does not have to be peripheral, if other hot spots become available elsewhere in the molecule.

This raises another point. Not much has been (can be?) said about the molecular chemistry of the grain. It is referred to as an 'aggregate' of H, C, N, O etc. I am rather interested in the possibility that this may include a fairly large mass (in view of the cosmic scale) of large macromolecules as well as the 'hydride ices' which are expected to be the most abundant molecular species on account of the incidence of H. Dufay hints that H should be discriminated against, but I am not entirely clear on the extent or theoretical basis of it, or whether this can be verified by experiments with molecular beams.

If these ideas are at all plausible, there are at least two nexi of interest between astrophysics and genetics: the evolution of thebgrain itself, and the scope of nonbiological synthesis of organic compounds. If there is any reality to the sequence:

free atoms—> interstellar grains —> comet —> micrometeoritic infall

the second feature may even play some role in the prebiotic synthesesof organic molecules on earth.

Dean Cowie and I are writing an 'interdisciplinary' article along these lines in connection with a forthcoming conference on biological applications of satellites, and I would very much appreciate your comment on these notions. It would also be most helpful to have reprints, if they are still available, of your papers dealing with these astrophysical problems.

Yours sincerely,

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